AGARD-AR-254

AGARD

ADVISORY GROUP FOR AEROSPACE RESEARCH & DEVELOPMENT

7 RUE ANCELLE 92200 NEUILLY SUR SEINE FRANCE

AGARD ADVISORY REPORT No.254

Technical Evaluation Report on the Fluid Dynamics Panel Symposium on Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing

NORTH ATLANTIC TREATY ORGANIZATION

DISTRIBUTION AND AVAILABILITY ON BACK COVER

NORTH ATLANTIC TREATY ORGANIZATION

ADVISORY GROUP FOR AEROSPACE RESEARCH AND DEVELOPMENT

(ORGANISATION DU TRAITE DE L'ATLANTIQUE NORD)

AGARD Advisory Report No.254

TECHNICAL EVALUATION REPORT

on the

FLUID DYNAMICS PANEL SYMPOSIUM

on

AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING

by

Marion L.Laster, Ph.D., P.E.
Technical Director
Directorate of Technology
Deputy for Operations
Arnold Engineering Development Center
Arnold AFB, TN 37389, USA

This Advisory Report was produced at the request of the Fluid Dynamics Panel of AGARD.

THE MISSION OF AGARD

According to its Charter, the mission of AGARD is to bring together the leading personalities of the NATO nations in the fields of science and technology relating to aerospace for the following purposes:

- Recommending effective ways for the member nations to use their research and development capabilities for the common benefit of the NATO community;
- Providing scientific and technical advice and assistance to the Military Committee in the field of aerospace research and development (with particular regard to its military application);
- Continuously stimulating advances in the aerospace sciences relevant to strengthening the common defence posture;
- Improving the co-operation among member nations in aerospace research and development;
- Exchange of scientific and technical information;
- Providing assistance to member nations for the purpose of increasing their scientific and technical potential;
- Rendering scientifie and technical assistance, as requested, to other NATO bodies and to member nations in connection with research and development problems in the aerospace field.

The highest authority within AGARD is the National Delegates Board consisting of officially appointed senior representatives from each member nation. The mission of AGARD is carried out through the Panels which are composed of experts appointed by the National Delegates, the Consultant and Exchange Programme and the Aerospace Applications Studies Programme. The results of AGARD work are reported to the member nations and the NATO Authorities through the AGARD series of publications of which this is one.

Participation in AGARD activities is by invitation only and is normally limited to citizens of the NATO nations.

The content of this publication has been reproduced directly from material supplied by AGARD or the author.

Published July 1988

ISBN 92-835-0468-2

Printed by Specialised Printing Services Limited
40 Chigwell Lane, Loughton, Essex IG10 3TZ

SUMMARY

This report presents a technical evaluation and assessment of the AGARD Fluid Dynamics Panel Symposium on "Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing", held 28 September to 1 October 1987 in Naples, Italy. The three major issues the Symposium addressed were:

- what are the actual demands in terms of data accuracy that the users have on facilities?
- what accuracy is presently achieved in our modern facilities?
- what measures can be taken to improve the situation?

Users have demanded a requirement that cruise drag be measured to a precision of one drag count for transports and two drag counts for military fighters. This requirement was demonstrated possible. It must be emphasised that this demand is practical when reference methods are possible. No statements of requirements were offered for the direct scaling concept. Certainly, one or two drag count uncertainty in this case is not state-of-the-art.

Improving the state-of-the-art will require a thorough understanding of all those parameters which significantly contribute to wind tunnel uncertainty, both bias and precision. A reduction in total uncertainty appears possible but a reduction to a level of one or two drag counts also appears formidable.

It is recommended that the wind tunnel community standardize its approach to dealing with data uncertainty.

* * *

Ce rapport représente une évaluation technique du Symposium organisé par le Panel AGARD de la Dynamique des fluides à Naples en Italie du 28 septembre au 1er octobre 1987, sur le thème "La précision et les exigences en matière de qualité des données aérodynamiques: Les possibilités offertes par les essais en soufflerie".

Les trois questions principales débattues lors du symposium furent les suivantes:

- que demandent réellement les utilisateurs concernant la précision des données sur les moyens dont ils disposent?
- quelle est la précision atteinte par nos moyens modernes à l'heure actuelle?
- quelles sont les mesures à prendre afin d'améliorer la situation?

Les utilisateurs ont demandé à ce que la traînée en croisière soit mesurée avec une précision d'un point de traînée sur les aéronefs de transport et de deux points pour les avions de combat. La faisabilité de cette opération a été démontré. Pourtant, il est à souligner que de telles mesures sont seulement réalisables que lorsque des méthodes de référence sont possibles. Aucune description des spécifications n'a été donnée en ce qui concerne le concept de pesée directe. Il est clair qu'une imprécision d'un ou de deux points de traînée dans ce cas n'est pas representatif de l'état de l'art.

Toute amélioration de l'état de l'art dans ce domaine passe nécessairement par une étude approfondie de tous les facteurs ayant une influence significative sur l'imprécision de résultats en soufflerie, quel que soit l'altération ou la précision des mesures.

Bien qu'une diminution globale d'imprécision semble réalisable, l'obtention d'une précision d'un ou deux points de traînée reste une tâche ardue.

En conclusion, il est recommandé aux experts en soufflerie de normaliser leurs méthodes, face au problème de l'imprécision des données.

CONTENTS

TECHNICAL EVALUATION REPORT OF THE SYMPOSIUM ON "AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING"

by

Marion L. Laster, Ph.D., P.E.
Technical Director
Directorate of Technology
Deputy for Operations
Arnold Engineering Development Center
Arnold Air Force Base, Tennessee 37389
USA

1. INTRODUCTION

The theme of this symposium pointed out that the main instrument of experimental aerodynamics continues to be the wind tunnel. Also theoretical computations using sophisticated CFD procedures have become a most useful added tool to the designer, but CFD verification has placed an added requirement upon the wind tunnel experimentalist for high quality experimental data. Three questions were raised by the theme of the symposium.

- What are the actual demands in terms of data accuracy that the users have on facilities?
- What accuracy is presently achieved in our modern facilities?
- What measures can be taken to improve the situations?

Assessment of how well these questions were answered will be addressed in the Conclusions, Section 3.0. This report will not attempt an evaluation of each individual paper but attempt to offer some general observations on each session. It is not within the evaluator's capability to offer expert commentary on each paper, consequently it will not be attempted. Besides, my view of the value of a contribution may have some bias, to use an often used term of the symposium, based on my background, that could be opposite and completely different than that of another just as equally valid view.

2. TECHNICAL DISCUSSION

2.1 GENERAL - The terminology used throughout the symposium by various authors was troublesome and sometimes inconsistent between papers, which led to confusion in the discussion of the overall subject of "accuracy." The words accuracy, error, data repeatability, uncertainty, precision, etc. were repeatedly used but there was little uniformity in the use of the terms. For example, quite often the term "accuracy" was used to mean precision uncertainty and at other times it indicated total uncertainty as well as repeatability. The propulsion test community has adopted a reasonably consistent terminology. Perhaps the wind tunnel community could adopt the same terminology or at least an attempt should be made to use a consistent set of terminology. Three papers were noted to use consistent terminology, i.e. references 5, 7, and 8. These terms basically are uncertainty, bias, and precision. The total uncertainty is defined to be made up of bias and precision terms. The same references used a similar math model to calculate bias and precision which also serves an excellent basis for comparing data uncertainty.

Most papers presented in the symposium dealt with data taken from low speed and transonic wind tunnels. One paper addressed problems with hypersonic Mach number characterization. The session on requirements, references 31 - 34, presented excellent discussions of goals to achieve in wind tunnel testing. As was pointed out by Krenz, Reference 31, current day aircraft, especially transport aircraft, can rely on "reference methods" to design aircraft. Reference methods have proven to work very well. They, however,do depend upon a well substantiated data base (from developed aircraft) which generally exists for subsonic and transonic transport aircraft. Reference methods have proven reliable using data from conventional wind tunnels for small configuration changes. Whenever a baseline of data does not exist "direct scaling" techniques must be employed. In this case the designer is faced with predicting flight performance based only on wind tunnel results, perhaps aided by analytical calculation. Therefore, the many uncertainties built into the wind tunnel data from sources such as lack of Reynold's number simulation, tunnel effects, and instrumentation contribute to a substantial overall uncertainly. The paper by Whoric and Hobbs, Reference 5, showed this by calculating a total uncertainty based on extrapolating wind tunnel data to flight. For a transport configuration the total uncertainty was as much as 40 drag counts or about 15% of total cruise drag. This is probably a worst case but it does illustrate the large uncertainty which can arise from using "direct scaling " techniques. With completely new configurations operating in an uncharted flight regime "direct scaling" may be the only choice until a developmental data base is established. Hypersonic aircraft development is experiencing this problem even now.

Several papers mentioned that the designer prefers a precision of one drag count from the wind tunnel for transport configurations. Several papers also showed that a precision of one drag count was possible in wind tunnel test, provided great diligence and care was taken.

For military fighter aircraft a measurement precision of two drag counts is acceptable for cruise and five drag counts for low speed testing. These requirements are also within the capabilities of current wind tunnel testing techniques. According to Ewald, Reference 27, cryogenic balance state-of-the-art has not developed to the point of measuring drag to a precision of one or two drag counts. The basic problem is designing a balance that compensates for or is insensitive to thermal gradients. An obvious question then is which approach provides least uncertainty: cryogenic testing at high Reynold's number or testing at conventional temperatures in conventional low Reynold's number wind tunnels and extrapolating the data to flight Reynold's number. The answer to this question is not obvious but I'm sure the aircraft designe

would want to know before planning his test program. Other considerations including cost are important also.

Those things which contribute to bias uncertainty in the wind tunnel include, for example, wall and support interference, tunnel turbulence level, flow quality, viscous simulation, internal flow corrections, base and cavity effects, aeroelasticity, etc. It should be realized by all aircraft designers that many of these bias effects are tunnel dependent and, when comparisons are made of aerodynamic data between tunnels, differences are to be expected. Often, reconciling data between wind tunnels is very challenging. But the aircraft designer and tunnel operator need to reconcile data to understand causes of data uncertainty. Better flight predictions will result especially when "direct scaling" techniques are used or required.

2.2 Wind Tunnel Data Comparison - SESSION I - In Session I we had more than one vivid illustration of the difficulty of thoroughly understanding data on similar or identical configurations taken from different wind tunnels. It seems that all data in some way must be adjusted to account for at least some "tunnel effect" or effects. All of the data presented in this session was subsonic or transonic aerodynamic data. One wonders as our interest grows again toward supersonic and hypersonic flows just what problems in wind tunnel data interpretation will present themselves. We will be confronted by the reduction of some problems, such as wall interference perhaps, but take on the added complexity of real gas aerodynamics and the difficulties of duplicating flight conditions.

This session has reconfirmed the value and importance of comparing aerodynamic data on the same model in different wind tunnels. These exercises usually reward us with a better understanding of our respective wind tunnels, adjustments, and corrections which must and should be applied to aerodynamic data. In this connection I was somewhat bothered by seeing comparisons made between wind tunnels when free transition is used. Free transition has its place in conducting wind tunnel investigations, but tunnel-to-tunnel comparisons will be at best difficult and questionable without fixing transition.

2.3 Uncertainty Analysis - SESSION II - Two papers dealt with wind tunnel results and two with propulsion test results. Uncertainty analysis has been used routinely in the propulsion test community for several years. Although a paper, Reference 5, in this session presented a similar analysis to four wind tunnel case studies, the procedure does not appear to be universally routine. Perhaps the wind tunnel community can learn something here from the propulsion test community. If the wind tunnel community could agree to a proper mathematical model, a more structured basis for characterizing and comparing results from different wind tunnels would exist. We must bear in mind that such analysis does not contribute to physical insight, but it does form a common basis for comparing contributions of all factors which contribute to uncertainty. As was pointed out in Reference 5 such analysis can also give "fiscal" guidance to solve problems giving the highest pay off. The quoted balance uncertainties for the cruise conditions do seem a bit frightening; these are mostly bias uncertainties, however. Improved balance design and calibration appears justified. Both wind tunnel papers in Session II also reminded us of the importance of having a proper force accounting system for the configuration of interest. Facility flow quality should be well known, proven test techniques used, boundary layer simulation well thought out, wall interference accounted for, and propulsion interactions thoroughly evaluated.

2.4 Drag Accuracy Achievements - SESSION III - In this session an assortment of activities were presented, including new afterbody drag measurement rigs, some recent drag measurements and procedures, flow stability effects on drag measurements, and some direct and inferred statements about drag accuracy measurements. The term accuracy is somewhat confusing. The papers use this term in the context of repeatability or precision for the most part, but not always. A precision uncertainty of one or two drag counts has been shown to be possible.

The effort to reduce test cost by using continuous sweep testing certainly has merit, but as shown there is a penalty to pay in force measurements that might not be acceptable, depending on uncertainty requirements.

It was noted that one drag count on the A310 was equivalent to 0.01 deg angle-of-attack. Knowing flow angularity to 0.02^{o} deg is a challenge itself. At this point in the symposium a clear statement on force measurement requirements and wind tunnel capabilities had not been made. The AEDC data of 20 to 40 drag counts uncertainty was not very comforting. However, ARA has set their goal at 5 counts, which I take they believe is possible and practical.

2.5 Facility Problems - SESSION IV - Session IV dealt with a number of facility issues including flow unsteadiness, nozzle design on flow quality, wall interference and support interference. With regard to flow unsteadiness it seems mandatory that this be characterized for every wind tunnel, as well as how free transition is affected. Otherwise boundary layer simulations cannot be adequately addressed. Neither can free-transition comparisons be addressed between facilities.

Another point worth noting, and vividly shown in this session, is that CFD has become very useful to the wind tunnel experimentalist. The qualitative and sometimes quantitative design of model supports and other devices as well as definition of their interference effects can be routinely handled, providing much less trial-and-error in designing test capabilities.

This session also had three papers dealing with the wall boundary effects on aerodynamic data. To me the uncertainty caused by wall boundary effects can be thought of as a <u>bias</u> which is a function of the wall configuration and model configuration and size. In the context of this symposium perhaps we should begin to think this way. Transonic wall interference is not a satisfactorily solved problem as yet. We do have considerable attention on this issue in Europe and North America and useful solutions may be near. We already know adaptive walls work and this may be the ultimate solution, especially if wall interference assessment and corrective procedures become too complex and computationally involved.

2.6 Simulation Problems - SESSION V - In Session V we first heard reports on the results of WG09 activity on boundary layer simulation and control for wind tunnel model testing. This working group has drawn

together a valuable reference document, which should serve the transonic wind tunnel community, industry, and researchers for a while until research has advanced this somewhat engineering "black art" to a more sound physical basis. The research committee's efforts have lead the way in this respect. The suggested methodology, as mentioned in the presentation, is not a cookbook, but it should serve as a basis for creating ordered thinking when boundary layer simulation is needed, which is most of the time.

Also it was mentioned that the results of this work will serve as the basis for an AGARD Special Course. The course is intended for engineers and researchers, wind tunnel people, aircraft designers, and academia who must deal with the subject.

This session also contained an excellent review of experimental buffet simulation techniques and problems using the wind tunnel to predict flight. Finally, turbine powered simulators and their calibration was discussed as related to transport aircraft testing. It was reported that 1 count repeatability was achievable for jet interaction experimental testing and a suggestion was made that this could be improved.

2.7 Progress in Testing Techniques - SESSION VI - In this session a very wide variety of subjects were discussed each of which is perhaps deserving of more extensive discussion. Although I said I would not comment about a specific paper I am making an exception. Prof Ewald's comments, Reference 7, and analysis about potential improvements in the conventional strain gage balance are particularly interesting and comforting, especially with repeatability requirements being one drag count or better. On the other hand the somewhat pessimistic outlook on cryogenic tunnel balances is not so comforting. Question: Can we extrapolate or correct low Reynold's data to high Reynold's number with less uncertainty than making measurements at high Reynold's number under cryogenic conditions?

2.8 - Requirements - SESSION VII - The final session of this symposium was on requirements. Wind tunnel requirements for CFD verification were addressed qualitatively with some quantification. We were given some excellent examples to help our thinking. We also had an excellent lecture on unsteady wind tunnel testing requirements and capabilities, some of the measurement techniques, and concepts for viscous effects simulation and wall interference. These concerns certainly sound familiar. Krenz, Reference 31, gave an excellent review of wind tunnel data precision requirements for transport aircraft.

3.CONCLUSIONS

In general the three theme question mentioned in the introduction of this report were addressed in this symposium and answers provided. Users have demanded a requirement that cruise drag be measured to a precision of one drag count for transports and two drag counts for military fighters. This requirement was demonstrated possible. Again it must be emphasized that this demand is practical when reference methods are possible. No statements of requirements were offered for the direct scaling concept. Certainly, one or two drag count uncertainty in this case is not state-of-the-art. Improving the state-of-the-art will require a thorough understanding of all those parameters which significantly contribute to wind tunnel uncertainty, both bias and precision. As mentioned earlier each wind tunnel has its own unique biases. Research and procedures developed will be needed in most instances for most tunnels to quantify corrections which should be applied to reduce total uncertainty. A reduction in total uncertainty appears possible but a reduction to a level of one or two drag counts also appears formidable. An assessment of the requirements in cases where direct scaling is needed should be done.

4.0 RECOMMENDATIONS

The wind tunnel community should standardize its approach to dealing with data uncertainty. Such a standard approach would provide a command basis for comparing wind tunnel results and possibly aid in improving flight performance predictions based on wind tunnel data. It would result in a better understanding of "Wind Tunnel"effects on data uncertainty. Perhaps the AGARD Fluid Dynamics Panel could sponsor a working group to address the issue and make detailed recommendations.

5. REFERENCES

5.1 Wind Tunnel Data Comparisons

1. McCroskey, W. J., A Critical Assessment of Wind Tunnel Results for the NACA 0012 Airfoil

2. Redeker, G., Muller, R., Ashill, P., Elsenaar, A., and Schmitt, V, Experiments of the DFVLR-F4 Wing-Body Configuration in Several European Wind Tunnels

3. Earnshaw, P. B., and Quemard, C., Comparaison des Résultats des Essais de l'A300 dans les Souffleries 5m du RAE et F1 de l'ONERA

4. Clark, R. D., and Rosenstein, H., Analytical and Experimental Methods Used to Resolve the Aerodynamic Results of Tests Conducted in Three Test Facilities.

5.2 Uncertainties Analysis

5. Whoric, J. M., and Hobbs, R. W., Hierarchy of Uncertainty Sources in Aerodynamic Coefficient Predictions Using Data from the AEDC Transonic Wind Tunnels 16T and 4T

6. Rooney, E. C., and Lauer, R. F., Wind Tunnel Predicted Air Vehicle Performance: A Review of Lessons Learned

7. Vleghert, J.P.K., Measurement Uncertainty of the AGARD/PEP Uniform Engine Test Programme

8. Kimzey, W. F., and Thompson, J. W. , An Overview of the Application of Standard Measurement Uncertainty Methodology to Propulsion Testing

5.3 Drag Accuracy Achievements

9. Wood, M. N., and Capps, D. S., The Accurate Measurement of Drag in the 8ft X 8ft Tunnel

10. Lawson G., and Cassie, A., Accurate Drag Estimation Using a Single Component Drag Model Technique

11. Carter, E. C., and Pallister, K. C., Flow Stability Measurements, Mach Number Requirements and Wind Tunnel Techniques in a Large Transonic Wind Tunnel to Achieve Required Drag Accuracy and Data Standards for Civil Transports

12. Armand, C., and Pujol, C., Amélioration de la Précision de la Mesure de la Trainée d'un Avion Civil. Moyens mis en Oeuvre en Soufflerie

5.4 Facility Problems

13. Michel, U., and Froebel, E., The Flow Unsteadiness in Three Low Speed Wind Tunnels

14. Van Every, D., S. Raimondo and Elfstrom, G. M., Impact of Wind Tunnel Adjustable Nozzle Design Constraints on Test Section Flow Quality

15. Crites, R. C., Transonic Wind Tunnel Boundary Interference - A Correction Procedure

16. Stanniland, D. R., The Use of Computational Fluid Dynamics Methods to Assess the Effects of Model Support Systems and Working Section Modifications on the Flow Around Wind Tunnel Models

17. Maarsingh, R. A., Labrujere, Th. E., Smith, J., Accuracy of Various Wall-Correction Methods for 3D Subsonic Wind Tunnel Testing

18. Lynch, F. T., Wind-Tunnel-Sidewall-Boundary-Layer Effects in Transonic Airfoil Testing - Some Correctable, but Some not

5.5 Simulation Problems

19. Stanewsky, E., Physical Aspects of Viscous Simulation and Associated Research Requirements

20. Elsenaar, A., Report of the Review Committee of AGARD 09 "Wind Tunnel Boundary Layer Simulation and Control"

21. Reshotko, E., A Proposed Boundary Layer Simulation Methodology

22. Russo, G. P., Experiments on Boundary Layer Transition Tripping at Low Reynolds Numbers

23. Destuynder, R., Schmitt, V., Des Difficultés de Prédure en Soufflerie le Tremblement d'un Avion Moderne. Rémèdes Proposès

24. Burgsmuller, W., Kool, J. W., and Moller, K. W., Accuracy Requirements for High-Speed Test with Engine Simulation on Transport Aircraft Models in the NLT-HST

25. Baumert, W., Binder, B., and Stager W., Engine Simulator Tests: Comparison of Calibration and Wind Tunnel Results

5.6 Progress in Testing Techniques

26. Drevet, J. P., Mesure des Efforts Instantanés sur une Maquette Soumise à des Variations Rapides de Commande

27. Ewald, B. F. R., Balance Accuracy and Repeatability as a Limiting Parameter in Aircraft Force Measurements in Conventional and Cryogenic Wind Tunnels

28. Boudreau, A. H., Jr., Characterization of Hypersonic Wind Tunnel Flow Fields for Improved Data Accuracy

29. Perinelle, J., and Ribadeau-Dum, M., Précision des Mesures De Portance et de Centre de Poussée de Gouvernes de Missiles

30. Monti, R., and Zuppardi, G., Computerized Thermographic Technique for the Detection of Boundary Layer Separation.

5.7 Requirements

31. Krenz, G., Accuracy Problems in Wind Tunnels During Transport Aircraft Development

32. Den Boer, R. G., Zwaam, R. J., On Requirements and Capabilities in Unsteady Aerodynamic Wind Tunnel Testing

33. Pianko, M., Spécifications Particulières Concernant les Résultats des Essais en Soufflerie pour la Mécanique du Vol

34. Marvin, J. G., Wind Tunnel Requirements for Computational Fluid Dynamics Code Vérification

REPORT DOCUMENTATION PAGE

1. Recipient's Reference	2. Originator's Reference	3. Further Reference	4. Security Classification of Document
	AGARD-AR-254	ISBN 92-835-0468-2	UNCLASSIFIED

5. Originator Advisory Group for Aerospace Research and Development
North Atlantic Treaty Organization
7 rue Ancelle, 92200 Neuilly sur Seine, France

6. Title
AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING

7. Presented at

8. Author(s)/Editor(s)	9. Date
Marion L.Laster, Ph.D., P.E.	July 1988

10. Author's/Editor's Address	11. Pages
Technical Director, Directorate of Technology Deputy for Operations Arnold Engineering Development Center Arnold AFB, TN 37389, USA	12

12. Distribution Statement This document is distributed in accordance with AGARD policies and regulations, which are outlined on the Outside Back Covers of all AGARD publications.

13. Keywords/Descriptors

Aerodynamic characteristics
Accuracy
Wind tunnels
Precision
Measurement

14. Abstract

This report presents a technical evaluation and assessment of the AGARD Fluid Dynamics Panel Symposium on "Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing", held in September 1987 in Naples, Italy. The major issues addressed were: what data accuracy do users need; what accuracy is presently achieved; and what can be done to improve the situation? Users have asked that cruise drag be measured to a precision of one drag count for transports and two for military fighters; and it was shown that this is possible when reference methods can be used. However, one or two drag count uncertainty is not state-of-the-art for the direct scaling concept and improvement will require a thorough understanding of all those parameters which significantly contribute to wind tunnel uncertainty, including bias and precision. A reduction in total uncertainty appears possible but a reduction to a level of one or two drag count also appears formidable.

AGARD Advisory Report No.254
Advisory Group for Aerospace Research and Development, NATO
AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING
by Marion L.Laster, Ph., P.E.
Published July 1988
12 pages

This report presents a technical evaluation and assessment of the AGARD Fluid Dynamics Panel Symposium on "Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing", held in September 1987 in Naples, Italy. The major issues addressed were: what data accuracy do users need; what

P.T.O

AGARD-AR-254

Aerodynamic characteristics
Accuracy
Wind tunnels
Precision
Measurement

AGARD Advisory Report No.254
Advisory Group for Aerospace Research and Development, NATO
AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING
by Marion L.Laster, Ph., P.E.
Published July 1988
12 pages

This report presents a technical evaluation and assessment of the AGARD Fluid Dynamics Panel Symposium on "Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing", held in September 1987 in Naples, Italy. The major issues addressed were: what data accuracy do users need; what

P.T.O

AGARD-AR-254

Aerodynamic characteristics
Accuracy
Wind tunnels
Precision
Measurement

AGARD Advisory Report No.254
Advisory Group for Aerospace Research and Development, NATO
AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING
by Marion L.Laster, Ph., P.E.
Published July 1988
12 pages

This report presents a technical evaluation and assessment of the AGARD Fluid Dynamics Panel Symposium on "Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing", held in September 1987 in Naples, Italy. The major issues addressed were: what data accuracy do users need; what

P.T.O

AGARD-AR-254

Aerodynamic characteristics
Accuracy
Wind tunnels
Precision
Measurement

AGARD Advisory Report No.254
Advisory Group for Aerospace Research and Development, NATO
AERODYNAMIC DATA ACCURACY AND QUALITY: REQUIREMENTS AND CAPABILITIES IN WIND TUNNEL TESTING
by Marion L.Laster, Ph., P.E.
Published July 1988
12 pages

This report presents a technical evaluation and assessment of the AGARD Fluid Dynamics Panel Symposium on "Aerodynamic Data Accuracy and Quality: Requirements and Capabilities in Wind Tunnel Testing", held in September 1987 in Naples, Italy. The major issues addressed were: what data accuracy do users need; what

P.T.O

AGARD-AR-254

Aerodynamic characteristics
Accuracy
Wind tunnels
Precision
Measurement

accuracy is presently achieved; and what can be done to improve the situation? Users have asked that cruise drag be measured to a precision of one drag count for transports and two for military fighters; and it was shown that this is possible when reference methods can be used. However, one or two drag count uncertainty is not state-of-the-art for the direct scaling concept and improvement will require a thorough understanding of all those parameters which significantly contribute to wind tunnel uncertainty, including bias and precision. A reduction in total uncertainty appears possible but a reduction to a level of one or two drag count also appears formidable.

ISBN 92-835-0468-2

accuracy is presently achieved; and what can be done to improve the situation? Users have asked that cruise drag be measured to a precision of one drag count for transports and two for military fighters; and it was shown that this is possible when reference methods can be used. However, one or two drag count uncertainty is not state-of-the-art for the direct scaling concept and improvement will require a thorough understanding of all those parameters which significantly contribute to wind tunnel uncertainty, including bias and precision. A reduction in total uncertainty appears possible but a reduction to a level of one or two drag count also appears formidable.

ISBN 92-835-0468-2

accuracy is presently achieved; and what can be done to improve the situation? Users have asked that cruise drag be measured to a precision of one drag count for transports and two for military fighters; and it was shown that this is possible when reference methods can be used. However, one or two drag count uncertainty is not state-of-the-art for the direct scaling concept and improvement will require a thorough understanding of all those parameters which significantly contribute to wind tunnel uncertainty, including bias and precision. A reduction in total uncertainty appears possible but a reduction to a level of one or two drag count also appears formidable.

ISBN 92-835-0468-2

accuracy is presently achieved; and what can be done to improve the situation? Users have asked that cruise drag be measured to a precision of one drag count for transports and two for military fighters; and it was shown that this is possible when reference methods can be used. However, one or two drag count uncertainty is not state-of-the-art for the direct scaling concept and improvement will require a thorough understanding of all those parameters which significantly contribute to wind tunnel uncertainty, including bias and precision. A reduction in total uncertainty appears possible but a reduction to a level of one or two drag count also appears formidable.

ISBN 92-835-0468-2